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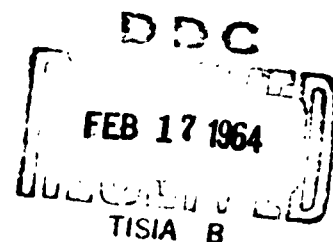
STRUCTURAL MATERIALS DIVISION

STRESS-CORROSION CRACKING
OF HIGH-STRENGTH ALLOYS

A Report To

FRANKFORD ARSENAL

Contract DA-04-495-ORD-3069



Report No. 0414-02-2 (Quarterly) / January 1964 / Copy No.

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January 1964

AEROJET-GENERAL CORPORATION
A SUBSIDIARY OF THE GENERAL TIRE & RUBBER COMPANY

This is the eleventh in a series of quarterly progress reports submitted in partial fulfillment of contract DA-04-495-ORD-3069. It constitutes the second quarterly progress report for the second 1-year continuation of the original 2-year program.

This report covers the period 1 October through 31 December 1963. It was written by R. B. Setterlund, who was supervised by A. Rubin.

AEROJET-GENERAL CORPORATION


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I. OBJECTIVES

The objectives of the program are outlined below.

A. To study the stress-corrosion characteristics of 18%-nickel maraging steel with respect to compositional variation.

B. To study the effect of environmental temperature on the rate of stress-corrosion cracking in three alloys: 18%-nickel maraging steel, a low-alloy martensitic steel, and a hot-worked die steel.

C. To study the electropotential changes occurring in 18%-nickel maraging steel during stress-corrosion exposure and the effect of applied potential.

D. To evaluate the effectiveness and applicability of surface protection on 18%-nickel maraging steel in preventing stress-corrosion cracking.

II. WORK PROGRESS

A. BACKGROUND

The present program is the second 1-year extension of the original 2-year program on stress-corrosion cracking of high-strength alloys. During the first 2-year study, six alloys were evaluated: Ladish D6AC steel; Type 300 M steel; Vascojet 1000 steel; AM 355 cold-worked PH steel; precipitation-hardening 15-7Mo stainless steel; and Bl20VCA titanium. Significant failures were found to occur with the D6AC, 300 M, and Vascojet 1000 steels in tap, distilled, and salt water, as well as in high-humidity environments; the time to failure for each of the three steels was found to decrease with increasing strength.

During the first 1-year continuation program, attention was focused on three new high-strength steels plus one high-strength titanium alloy. These alloys are (1) 20%-nickel maraging steel, (2) 18%-nickel maraging steel, (3) 9Ni-4Co vacuum melted steel, and (4) 6Al-4V titanium. The titanium alloy showed complete immunity

to stress-corrosion failure under all test conditions. Limited susceptibility was noted for the 9Ni-4Co alloy. High susceptibility was noted with both the 20% and 18%-nickel maraging steels. Since the original study of maraging steels was started, the 18%-nickel grade has received increased attention in the aerospace industry, and is now of primary interest. The present program is therefore directed to the study of the stress-corrosion behavior of this one alloy, with emphasis on compositional variation, effect of environmental temperature, and study of electropotential changes. It is intended to: first, determine the extent of the stress-corrosion problem in 18%-nickel maraging steel by testing four additional heats; second, compare the susceptibility of maraging steel with conventional ultra-high-strength steels; and, third, to investigate further, by electropotential methods, the cause of failure of 18%-nickel maraging steel.

B. TEST PROCEDURES

1. Bent Beam Test

The bent-beam test is the primary test method used in the program. Figure 1 shows an insulated bent-beam fixture with test samples mounted. Polycarbonate blocks 7.000 ± 0.001 in. apart, attached to a stainless-steel holder, support the test specimen and insulate it from the holder. Specimens are cut to exact length to give a maximum outer-fiber stress of 75% of the 0.2% offset yield strength. The length-stress relationship is shown in Figure 2.

2. U-Bend Test

In addition to the bent beam testing, U-bend samples are used to show the effect of elastic stresses combined with plastic deformation. Samples are bent in a special 1 in. radius fixture after heat treatment and cleaning. Samples which were known to have a low ductility were warmed to 100 to 175°F prior to bending.

3. Center Notch Test

Figure 3 shows the test specimen configuration used in the accelerated center-notch test. This consists of a 1-3/4- by 8-in. tensile specimen containing a central notch. The notch is produced by a two-step process. First, a 0.06- by 0.57-in. slot is Elox machined and extended at each end by very narrow

Elox-machined notches of 0.001-in. root radii. Second, an extension of these notches is produced by tension-fatigue cycling to obtain fatigue cracks of controlled dimensions.

These center-notched specimens are tested in Baldwin creep-test machines. The desired loads are obtained by dead weight loading applied to a 20 to 1 lever arm. The test environment is applied by cementing a polyethylene cup to the specimen in the area of the notch. These specimens are well adapted to stress-corrosion studies in that crack growth rate, corrosion potential, or corrosion current can be conveniently measured.

4. Test Environments

The test environments in this program include those that the results of the previous year's program indicated were the cause of the most rapid failure of maraging steel; these are: continuous immersion in aerated distilled water; continuous immersion in aerated distilled water containing 3% by weight chemically pure sodium chloride; water-saturated air at 140°F; and natural seacoast atmospheric exposure. In addition, two new environments are being employed: distilled water at a thermostatically regulated temperature of $120 \pm 0.1^\circ\text{F}$; and distilled water thermostatically regulated to $160 \pm 0.1^\circ\text{F}$. All baths are changed every 10 to 14 days.

C. PROGRAM STATUS

1. Compositional Variation

In order to determine the effect of compositional variation on stress corrosion of 18%-nickel maraging steel, Aerojet is testing four commercial heats of the material in environments that were found, in the previous year's work, to produce the most rapid failures. The compositional variation of these four heats are shown in Table 1, Group b. The only element showing wide variation is titanium, which varies from 0.23 to 0.55%. Mechanical properties of the four heats are shown in Table 2, Group b.

Triplicate bent-beam and U-bend specimens of each of these four heats of material have been exposed to aerated distilled water (Table 3), aerated 3%-sodium chloride solution (Table 4), and 140°F water-saturated air (Table 5).

The most severe test condition has been found to be water-saturated air (high humidity) at 140°F. All specimens from each of the four heats failed; the individual lifetimes ranged from 3 to 27 days for U-bend specimens and 7 to 65 days for bent beam specimens. No well-defined relationship between failure time and compositional variation has been obtained, although the 0.23%-titanium alloy is generally the least susceptible. Failures have been found to be intergranular. Three of the four heats of material have shown failures with both U-bend and bent beam specimens in the aerated distilled water and aerated salt water environments. The fourth heat has had a relatively short exposure time to date.

Specimens of D6AC steel are being exposed to these same environments. The data so far indicates that, in each of the three environments, the D6AC steel is more susceptible than 18%-nickel maraging steel at the 237-ksi yield-strength level (600°F) but is far less susceptible at the 203-ksi yield-strength level (1100°F).

2. Environmental Temperature

The second objective is to study the effect of environmental temperature on the rate of stress-corrosion cracking in three alloys: 18%-nickel maraging steel, a low-alloy martensitic steel (D6AC), and a hot-worked die steel (Vascojet 1000). To accomplish this, we are repeating the ambient tests in distilled water at temperatures of 120°F and 160°F. To date, only the tests at 120°F have been started. These results, Table 6, show slightly more rapid failures at 120°F than at ambient temperature for both the 18%-nickel maraging steel and the low-alloy martensitic steel.

3. Electrochemical Measurements

The third objective of the program is to measure the electrochemical changes occurring in 18%-nickel maraging steel during stress-corrosion exposure and to determine the effect of applied potential on failure time. A preliminary test has been conducted on a center-notched specimen of heat 3960502. The test setup is shown in Figure 4. Using this test procedure the stress-potential relationship shown in Figure 5 was obtained. As the stresses at the crack tip, K , increase by dead weight loading of the specimen, the metal is found to become more chemically active. This study is continuing.

4. Surface Preparation

The fourth objective of the present program is to evaluate the effectiveness and applicability of surface protection in preventing stress-corrosion cracking on 18%-nickel maraging steel. Three coating systems, which have shown some degree of effectiveness in preventing stress-corrosion cracking of H-11 steel that has been heat treated to a susceptible level, are being evaluated on a single heat of 18%-nickel maraging steel. Each of the three coatings offers a different means of protection. The polyurethane coating forms a dense barrier between the environment and the metal. The inorganic zinc coating serves to provide cathodic protection to the metal, while the inhibited-epoxy coating protects the metal both by forming a barrier and by chromate compounds within the coating. As shown in Table 7, maraging steel coated with the zinc-bearing coating fails more rapidly than uncoated material, while the polyurethane coating offers some protection. The chromate-inhibited epoxy coating is the most effective of the three in preventing stress-corrosion cracking on either H-11 or 18%-nickel maraging steel.

D. FUTURE WORK

Work during the remainder of the contract period will involve: (1) evaluation and environmental testing of the Vascojet 1000 material for comparison with materials in testing; (2) testing of all materials in 160°F distilled water and in seacoast environments, (3) electrochemical experiments to determine the effect of applied potential on stress corrosion and (4) continued evaluation of results to establish correlations.

TABLE 1
MIL-CERTIFIED CHEMICAL ANALYSIS OF PROGRAM MATERIALS

| Tr. & Name | Supplier | Heat No. | Composition, % | | | | | | | | | | | | | | |
|---|------------------|----------|----------------|-------|-------|-------|-------|-------|------|------|-------|------|-------|------|-------|--------|------|
| | | | C | W | P | S | Si | Mn | Co | Mo | Al | Cr | Zr | Ni | Ca | V | |
| *(a) Maraging Steel from Previous Program | | | | | | | | | | | | | | | | | |
| REM 250 | Republic Steel | 9960502 | 0.02 | 0.08 | 0.007 | 0.006 | 0.15 | 18.48 | 7.00 | 1.84 | 0.21 | 0.10 | 0.035 | 0.50 | - | 0.0036 | - |
| --- | Allegheny-Ludlum | 448 | 0.029 | 0.002 | 0.004 | 0.008 | 0.009 | 18.51 | 8.48 | 1.92 | 0.089 | - | - | 0.52 | - | - | - |
| Almar 18 | Allegheny-Ludlum | W-24178 | 0.012 | 0.01 | 0.003 | 0.005 | 0.01 | 18.69 | 8.90 | 4.92 | 0.029 | - | 0.003 | 0.62 | 0.006 | 0.002 | - |
| --- | Allegheny-Ludlum | 476 | 0.02 | 0.08 | 0.006 | 0.005 | 0.014 | 18.60 | 9.05 | 4.90 | 0.078 | - | - | 1.00 | - | - | - |
| Almar 20 | Allegheny-Ludlum | W-24254 | 0.009 | 0.09 | 0.002 | 0.005 | 0.06 | 20.41 | - | - | 0.29 | - | 0.002 | 1.40 | 0.004 | 0.003 | - |
| (b) Maraging Steel for Present Program | | | | | | | | | | | | | | | | | |
| REM 200 | Republic Steel | 9960523 | 0.029 | 0.06 | 0.005 | 0.006 | 0.05 | 17.79 | 8.50 | 3.48 | 0.13 | - | - | 0.23 | - | - | - |
| Vascomax 250 | Vanadium Alloys | 07868 | 0.02 | 0.09 | 0.004 | 0.005 | 0.10 | 17.75 | 7.60 | 4.60 | 0.08 | - | 0.017 | 0.52 | 0.05 | 0.004 | - |
| Marvac 18 | Latrobe Steel | C56858 | 0.03 | 0.03 | 0.004 | 0.008 | 0.05 | 18.34 | 8.00 | 4.75 | 0.11 | - | 0.03 | 0.49 | - | 0.004 | - |
| Vascomax 300 | Vanadium Alloys | 07268 | 0.03 | 0.05 | 0.004 | 0.006 | 0.04 | 18.54 | 9.06 | 4.88 | 0.09 | - | 0.088 | 0.55 | 0.02 | 0.003 | - |
| (c) Conventional High-Strength Steels | | | | | | | | | | | | | | | | | |
| Vascojet 1000 | Vanadium Alloys | 07914 | 0.38 | 0.21 | 0.010 | 0.008 | 0.92 | - | - | 1.33 | - | 4.75 | - | - | - | - | 0.51 |
| Ledush D6AC | Allegheny-Ludlum | W-25217 | 0.495 | 0.62 | 0.009 | 0.003 | 0.20 | 0.57 | - | 0.94 | - | 1.00 | - | - | - | - | 0.05 |

* Some material from previous program will be used to obtain supplementary data.

** Experimental 400-1b heats.

Table 1

TABLE 2
MECHANICAL PROPERTIES OF PROGRAM MATERIALS
(ADJUSTED DATA)

| Trade Name | Supplier | Heat No. | Heat Treatment Temp., °F Time, hours | 0.2% Offset Yield Strength ksi | Ultimate Tensile Strength ksi | % Elongation | % Reduction in Area | Rc Hardness | Crack Growth Energy (Cg) in.-lb/sq in. |
|--|-------------------|----------|--|--------------------------------------|--|-----------------|---------------------------|----------------|---|
| (a) Maraging Steel from Previous Program | | | | | | | | | |
| BSM 250 | Republic Steel | 3960502 | 900 | 249.9 | 254.7 | 4.0 | 37.0 | 50.5 | 670.0 |
| ** | Allegheny-Indiana | 448 | 900 | 255.4 | 265.9 | 5.0 | 9.0 | 52.0 | 694.0 |
| Almar 18 | Allegheny-Indiana | W-24178 | 900 | 283.0 | 294.0 | 8.0 | 38.0 | 53.5 | 552.0 |
| ** | Allegheny-Indiana | 476 | 900 | 323.5 | 330.0 | 2.5 | 27.0 | 56.0 | 402.0 |
| Almar 20 | Allegheny-Indiana | W-24254 | 850 | 291.3 | 302.2 | 3.0 | 17.0 | 54.0 | 58.5 |
| (b) Maraging Steel for Present Program | | | | | | | | | |
| BSM 200 | Republic Steel | 3960523 | 900 | 181.5 | 190.7 | 5.0 | 43.0 | 42.0 | 658.0 |
| Vascomax 290 | Vanadium Alloys | 07868 | 900 | 248.2 | 248.2 | 4.0 | - | 49.0 | 692.0 |
| Marvac 18 | Latrobe Steel | C56858 | 900 | 269.7 | 275.7 | 5.0 | 34.0 | 51.5 | 640.0 |
| Vascomax 300 | Vanadium Alloys | 07268 | 900 | 279.1 | 288.1 | 4.0 | 18.0 | 52.0 | 560.0 |
| (c) Conventional High-Strength Alloys | | | | | | | | | |
| Vascojet 1000 | Vanadium Alloys | 07914 | (To be evaluated) | | | | | | |
| Ladish D54C | Allegheny-Indiana | W-23217 | 600 | temper**** | 237.4 | 281.5 | 25.0 | 51.5 | 182.0 |
| | | | 800 | temper | 214.5 | 241.2 | 38.0 | 45.5 | 305.0 |
| | | | 900 | temper | 204.6 | 226.4 | 43.5 | 44.0 | 305.0 |
| | | | 1100 | temper | 203.1 | 218.5 | 46.0 | 44.0 | 303.0 |

* Some material from previous program will be used to obtain supplementary data.

** Experimental 400-lb heats.

*** Received 30% cold reduced, lab-annealed for 1 hour at 1500°F.

**** Normalized, 1675°F, for 1 hour, A.C.; Austenitized, 1650°F for 15 min, O.Q.

TABLE 3
STRESS-CORROSION TEST RESULTS
AERATED DISTILLED WATER

| Material | Heat No. | Yield | Failure* | Failure Time, hours** | |
|---------------------------|-----------------------|------------|----------|-----------------------|--------------|
| | | Strength | | Mean | Range |
| | | ksi | Ratio | | |
| Bent Beam Tests*** | | | | | |
| 20%-Ni Maraging Steel | W-24254 | 291.3 | 3/3 | 11 | 10.2-18 |
| 18%-Ni Maraging Steel | 3960523 | 181.5 | 0/3 | - | NF 1830 |
| ↓ | 07868 | 248.2 | 2/3 | 1030 | 980-NF 1080 |
| | 3960502 | 249.9 | 3/3 | 68 | 50-85 |
| | 056858 | 267.7 | 0/3 | - | NF 430 |
| | 07268 | 279.1 | 3/3 | 500 | 483-512 |
| | 18%-Ni Maraging Steel | W-24178 | 283.0 | 3/3 | 34.5 |
| D6AC Steel | W-23217 | 203.1 | 0/3 | - | NF 750 |
| ↓ | ↓ | 204.6 | 0/3 | - | NF 750 |
| | | 214.5 | 0/3 | - | NF 750 |
| | | D6AC Steel | W-23217 | 237.4 | 2/3 |
| U-Bend Tests**** | | | | | |
| 20%-Nickel Maraging Steel | W-24254 | 291.3 | 2/2 | 3.5 | 1.4-5.5 |
| 18%-Ni Maraging Steel | 3960523 | 181.5 | 1/3 | 1980 | 1900-NF 2070 |
| ↓ | 07868 | 248.2 | 2/3 | 880 | 480-NF 1540 |
| | 3960502 | 249.9 | 1/2 | 625 | 600-NF 650 |
| | 056858 | 267.7 | 0/3 | - | NF 24 |
| | 07268 | 279.1 | 2/3 | 1530 | 407-NF 2350 |
| | 18%-Ni Maraging Steel | W-23217 | 203.1 | 0/2 | - |
| D6AC Steel | ↓ | 204.6 | 0/2 | - | NF 940 |
| 214.5 | | 1/2 | 690 | 432-NF 940 | |
| D6AC Steel | | W-23217 | 237.4 | 2/2 | 4.0 |

*Ratio of samples failed to samples tested.

**"NF" indicates no failure at the time given.

***Samples stressed to 75% of yield point.

****Samples stressed beyond yield point.

Table 3

TABLE 4
STRESS-CORROSION TEST RESULTS
AERATED SALT WATER

| Material | Heat No. | Yield | Failure* | Failure Time, hours** | |
|-----------------------|----------|-----------------|----------|-----------------------|-------------|
| | | Strength ksi | | Ratio | Mean |
| Bent Beam Tests*** | | | | | |
| 20%-Ni Maraging Steel | W-24254 | 291.3 | 3/3 | 7.3 | 6-8.5 |
| 18%-Ni Maraging Steel | 3960523 | 181.5 | 0/3 | - | NF 1830 |
| | 07868 | 248.2 | 0/3 | - | NF 1080 |
| | 3960502 | 249.9 | 3/3 | 430 | 140-700 |
| | C56858 | 267.7 | 0.3 | - | NF 430 |
| | 07268 | 279.1 | 3/3 | 1070 | 119-1970 |
| 18%-Ni Maraging Steel | W-24178 | 283.0 | 3/3 | 52 | 19-100 |
| D6AC Steel | W-23217 | 203.1 | 0/2 | - | NF 750 |
| | | 204.6 | 0/3 | - | NF 750 |
| | | 214.5 | 0/3 | - | NF 750 |
| D6AC Steel | W-23217 | 237.4 | 1/3 | 580 | 240-NF 750 |
| U-Bend Tests**** | | | | | |
| 20%-Ni Maraging Steel | W-24254 | 291.3 | 2/2 | 2.4 | 1.9-2.9 |
| 18%-Ni Maraging Steel | 3960523 | 181.5 | 0/3 | - | NF 2070 |
| | 07868 | 248.2 | 1/3 | 1130 | 312-NF 1540 |
| | 3960502 | 249.9 | 0/0 | - | - |
| | C56858 | 267.7 | 0/3 | - | NF 24 |
| 18%-Ni Maraging Steel | 07268 | 279.1 | 0/3 | - | NF 2350 |
| D6AC Steel | W-23217 | 203.1 | 0/2 | - | NF 940 |
| | | 204.6 | 0/2 | - | NF 940 |
| | | 214.5 | 0/2 | - | NF 940 |
| D6AC Steel | W-23217 | 237.4 | 2/2 | 1.0 | 0.8-1.2 |

*Ratio of samples failed to samples exposed.

**"NF" indicates no failure at the time given.

***Samples stressed to 75% of yield strength.

****Samples stressed to beyond yield strength.

TABLE 5STRESS-CORROSION TEST RESULTS
140°F WATER-SATURATED AIR

| Material | Heat No. | Yield | Failure* | Failure Time, hours** | |
|-----------------------|----------|-----------------|----------|-----------------------|------------|
| | | Strength ksi | | Ratio | Mean |
| Bent Beam Tests*** | | | | | |
| 20%-Ni Maraging Steel | W-24254 | 291.3 | 3/3 | 100 | 22-174 |
| 18%-Ni Maraging Steel | 3960523 | 181.5 | 3/3 | 1500 | 1318-1560 |
| | 07868 | 248.2 | 3/3 | 600 | 480-722 |
| | 3960502 | 249.9 | 3/3 | 370 | 170-475 |
| | 056858 | 267.7 | 3/3 | 190 | 167-236 |
| | 07268 | 279.1 | 3/3 | 965 | 320-2040 |
| 18%-Ni Maraging Steel | W-24198 | 283.0 | 3/3 | 21 | 20.5-21.5 |
| D6AC Steel | W-23217 | 203.1 | 0/2 | - | NF 750 |
| | | 204.6 | 1/3 | 676 | 528-NF 750 |
| | | 214.5 | 3/3 | 333 | 309-381 |
| D6AC Steel | W-23217 | 237.4 | 3/3 | 142 | 72-213 |
| U-Bend Tests**** | | | | | |
| 18%-Ni Maraging Steel | 3960523 | 181.5 | 4/4 | 252 | 120-407 |
| | 07868 | 248.2 | 3/3 | 378 | 282-426 |
| | 3960502 | 249.9 | 2/2 | 167 | 167-167 |
| | 056858 | 267.7 | 3/3 | 70 | 70-70 |
| 18%-Ni Maraging Steel | 07268 | 279.1 | 3/3 | 527 | 470-640 |
| D6AC Steel | W-23217 | 203.1 | 0/2 | - | NF 940 |
| | | 204.6 | 2/2 | 372 | 244-500 |
| | | 214.5 | 2/2 | 217 | 191-244 |
| D6AC Steel | W-23217 | 237.4 | 2/2 | 1 | 1 |

*Ratio of samples failed to samples tested.

**"NF" indicates no failure at time given

***Samples stressed to 75% of yield strength.

****Samples stressed beyond yield strength.

TABLE 6
STRESS-CORROSION TEST RESULTS
120°F DISTILLED WATER

| Material | Heat No. | Yield | Failure* | Failure Time, hours** | |
|-----------------------|----------|-----------------|----------|-----------------------|------------|
| | | Strength ksi | | Ratio | Mean |
| Bent Beam Tests*** | | | | | |
| 18%-Ni Maraging Steel | 396052 | 181.5 | 0/3 | - | NF 770 |
| ↓ | 67868 | 248.2 | 3/3 | 532 | 500-596 |
| | 3960502 | 249.9 | 2/2 | 165 | 164-166 |
| | 056858 | 267.7 | 3/3 | 348 | 324-396 |
| 18%-Ni Maraging Steel | 07268 | 279.1 | 3/3 | 447 | 336-668 |
| D6AC Steel | W-23217 | 203.1 | 0/3 | - | NF 750 |
| ↓ | ↓ | 204.6 | 0/3 | - | NF 750 |
| | | 214.5 | 3/3 | 695 | 644-740 |
| D6AC Steel | W-23217 | 237.4 | 3/3 | 245 | 213-310 |
| U-Bend Tests**** | | | | | |
| 20%-Ni Maraging Steel | W-24254 | 291.3 | 3/3 | 347 | 180-668 |
| 18%-Ni Maraging Steel | 396052 | 181.5 | 3/3 | 359 | 245-500 |
| ↓ | 07868 | 248.2 | 3/3 | 196 | 180-218 |
| | 3960502 | 249.9 | 2/2 | 133 | 121-144 |
| | 056858 | 267.7 | 0/3 | - | NF 24 |
| 18%-Ni Maraging Steel | 07268 | 279.1 | 3/3 | 414 | 331-500 |
| D6AC Steel | W-23217 | 203.1 | 0/2 | - | NF 940 |
| ↓ | ↓ | 204.6 | 1/2 | 915 | 890-NF 940 |
| | | 214.5 | 2/2 | 537 | 335-740 |
| D6AC Steel | W-23217 | 237.4 | 2/2 | 2.3 | 1.6-3.0 |

* Ratio of samples failed to samples exposed

** "NF" indicates no failures at time given.

*** Samples stressed to 75% of yield strength.

**** Samples stressed beyond yield strength.

TABLE 7

BENT-BEAM STRESS CORROSION TESTS
FOR COATING EVALUATION

| Base Material | Coating | Aerated 3% NaCl Solution | | | 140°F Water-Saturated Air | | |
|-----------------------|-------------------------|--------------------------|--------------|-------------------|---------------------------|--------------|-------------------|
| | | Failure Ratio* | Failure Mean | Time, hours Range | Failure Ratio* | Failure Mean | Time, hours Range |
| H-11 Steel | None | 4/4 | 1.6 | 0.8-2.5 | 2/2 | 64 | 48-70 |
| | Polyurethane X-500 | 3/3 | 149 | 144-168 | 6/6 | 3500 | 2830-5500 |
| | Inorganic Zinc 11 | 2/2 | 687 | 674-702 | 2/2 | 821 | 728-819 |
| H-11 Steel | Inhibited Epoxy 454-1-1 | 0/2 | - | NF 3100 | 3/3 | 2720 | 2590-2850 |
| 18%-Ni Maraging Steel | None | 3/3 | 1068 | 119-1970 | 3/3 | 965 | 320-2040 |
| | Polyurethane X-500 | 0/3 | - | NF 1750 | 3/3 | 1513 | 1250-1728 |
| | Inorganic Zinc 11 | 3/3 | 339 | 72-648 | 3/3 | 150 | 140-170 |
| 18%-Ni Maraging Steel | Inhibited Epoxy 454-1-1 | 0/3 | - | NF 1750 | 1/3 | 1550+ | 1150-NF 1750 |

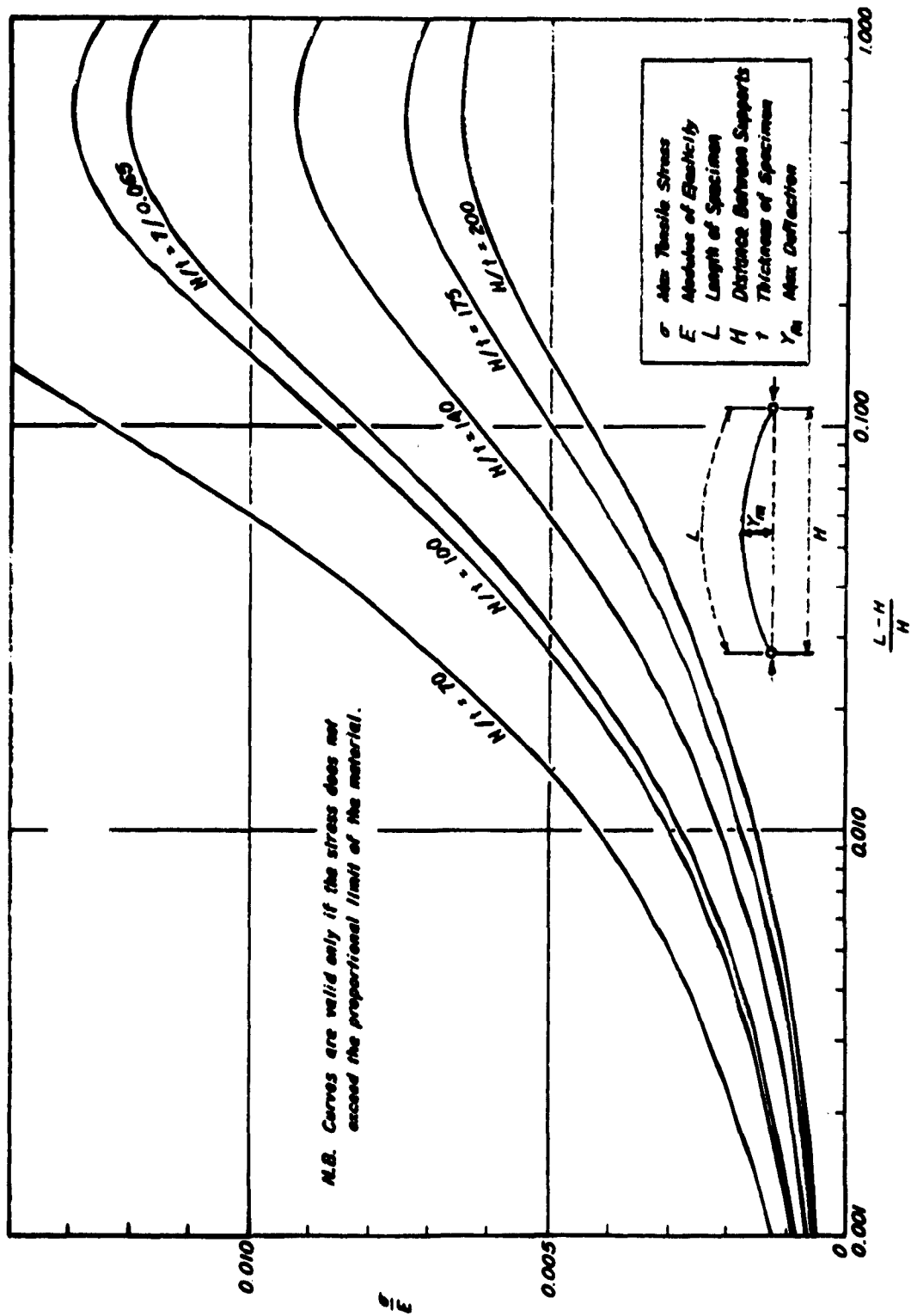
* Ratio of samples failed to samples exposed.

Table 7



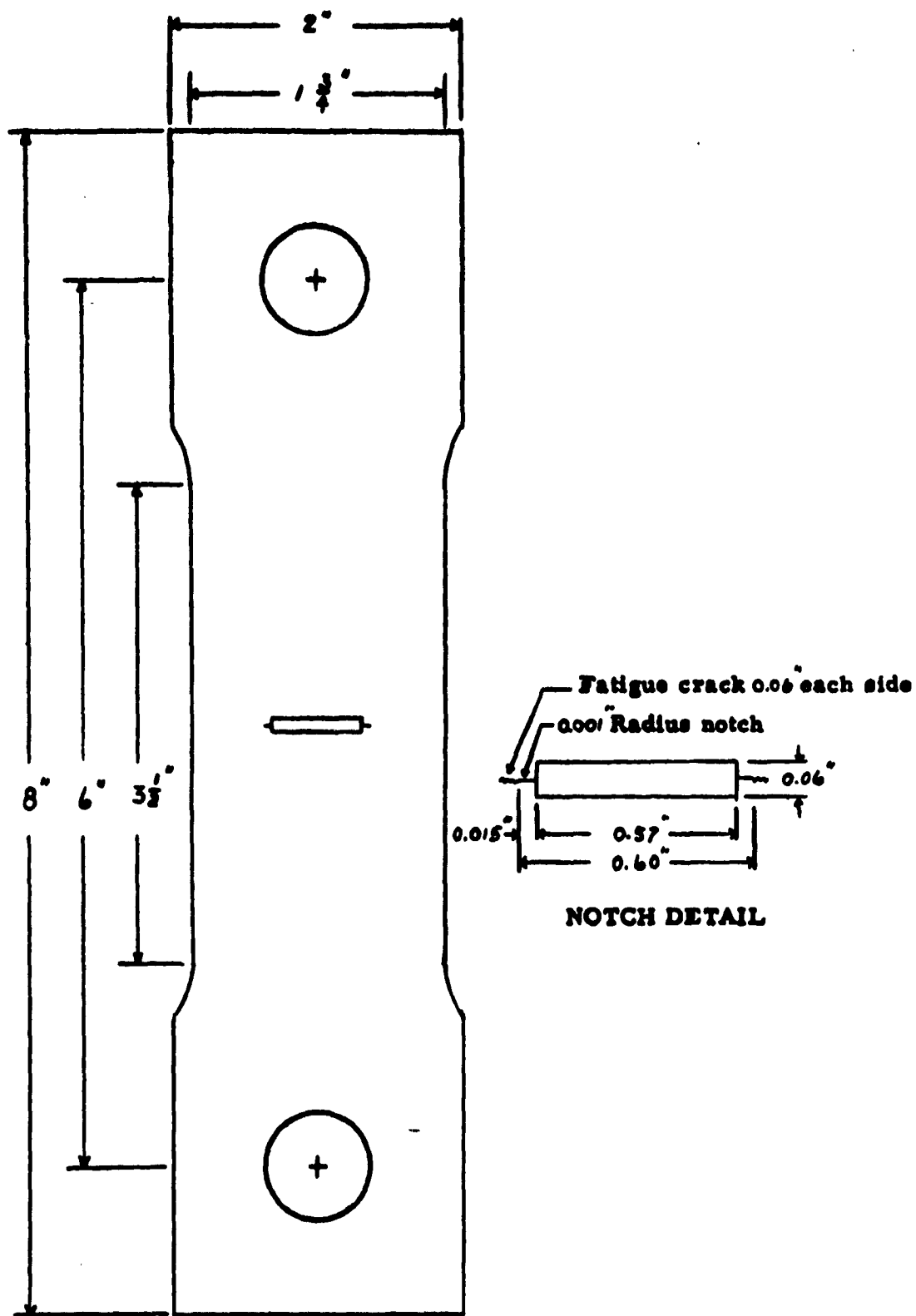
Bent-Beam Test Fixture and Specimens

Figure 1



Beam Length-Stress Relationship

Figure 2



Center-Notch Specimen Configuration

Figure 3

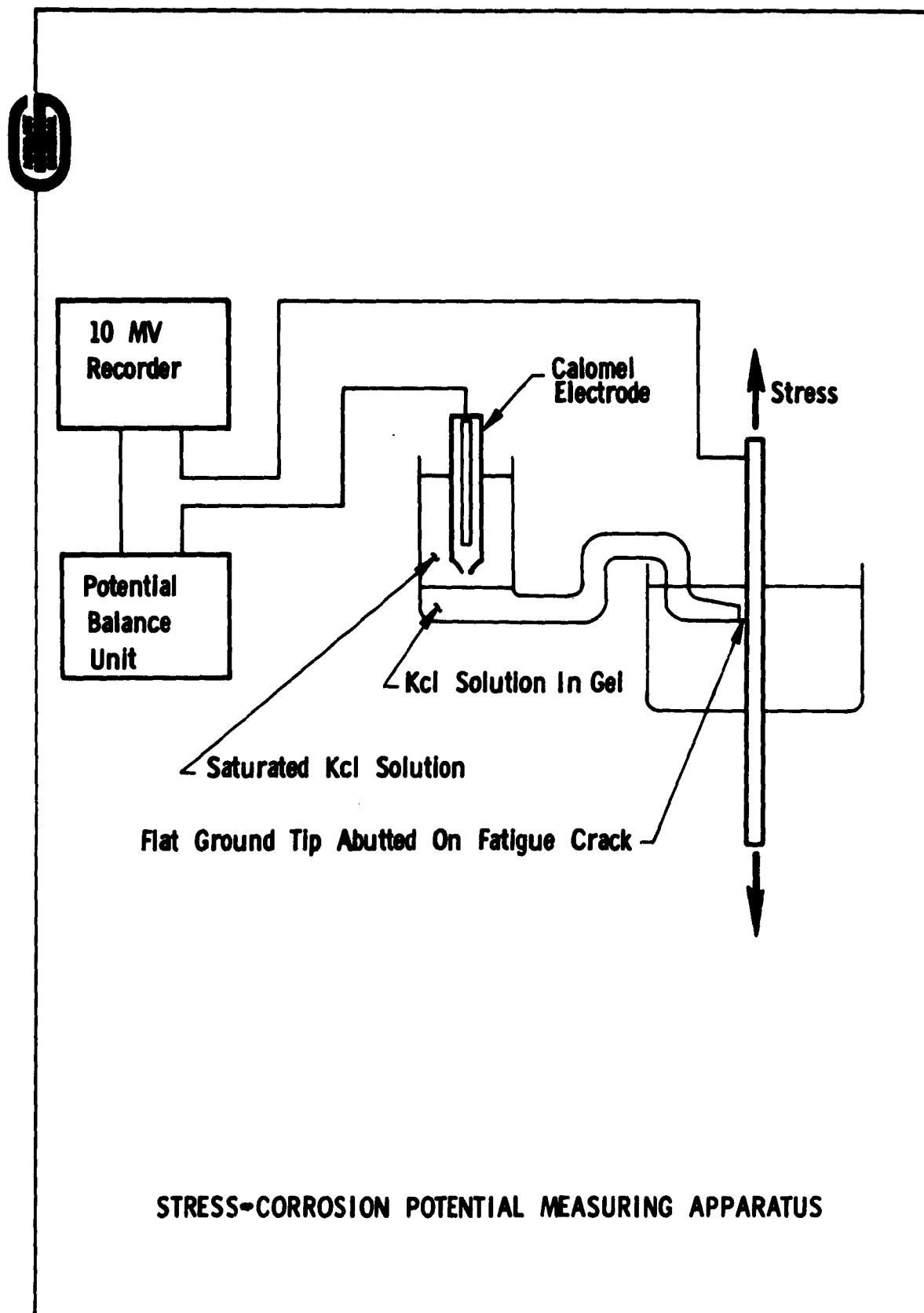
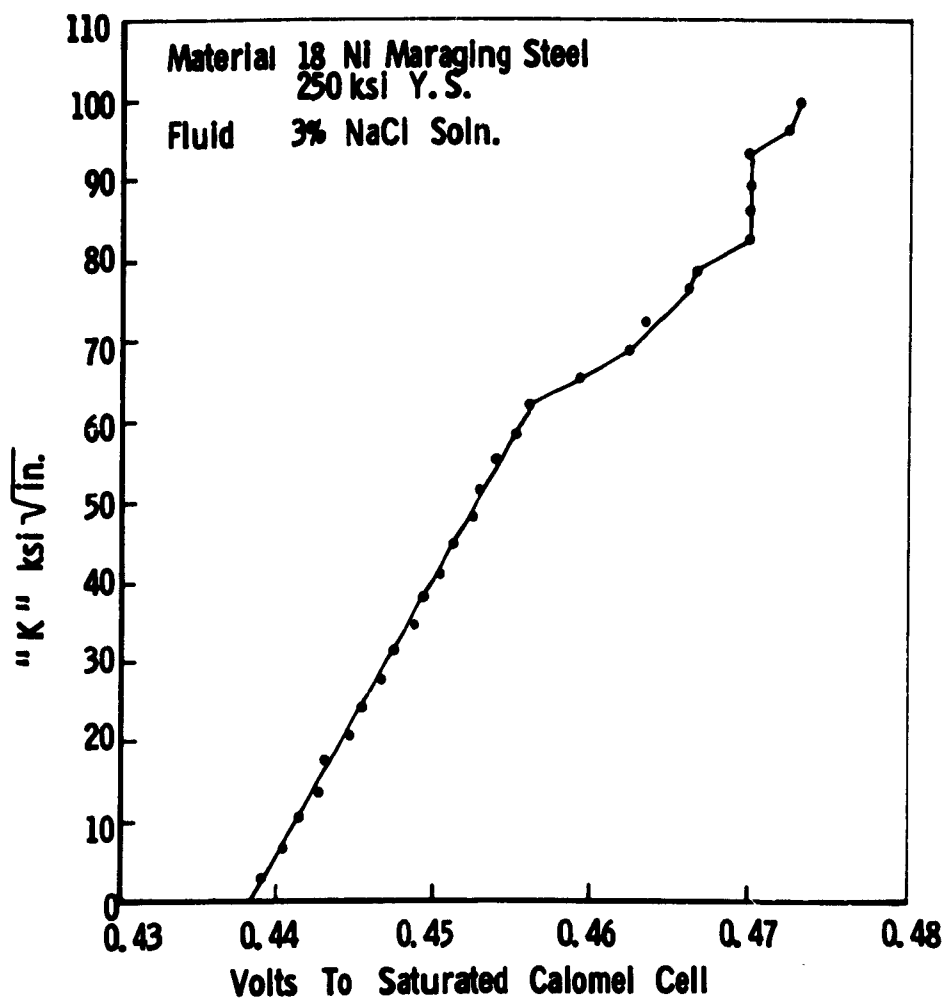


Figure 4



EFFECT OF STRESS FIELD PARAMETER, K, ON CRACK-TIP CORROSION POTENTIAL